

eRD10: R&D Proposal for (Sub) 10 picosecond Timing Detectors at the EIC

Progress Report, July – December 2014

The eRD10 Collaboration

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Abstract

The eRD10 program is pursuing improvements in time of flight technology to be used for particle identification in the 0-15 GeV range at the proposed electron-Ion Collider (eIC). Our proposal concentrated on two promising possibilities. The first was to develop a more UV sensitive LAPPD MCP-PMT using alternative windows such as fused silica coupled with more UV sensitive photocathodes. The increased photoelectron yield should improve the timing resolution over the standard LAPPD design. The second possibility was to explore ways to improve the best achieved resolution of multi-gap Resistive Plate Chambers (mRPC), which is currently 16 picoseconds. Some options proposed were to use heavier and faster gas mixtures, replace the glass dielectric with thinner alternatives, and reducing the gas gap sizes, all of which might improve the resolution.

What was planned for this period?

The EIC R&D funds provided for one post-doc at UIUC, which is enough to pursue various studies of improved mRPC design. For this current 6 month period we planned to get the cosmic ray test-stand at UIUC running, work on designs for improved prototypes, and begin microscopic simulations of the avalanche development in mRPCs using Garfield/Heed/Magboltz. The simulations will allow us to explore the phase space of parameters and allow us to constrain the options for improving the mRPC design.

In addition, to begin evaluating the performance of the detector for physics, full GEANT4 simulations of the sensitivity to quark transversity distributions using TOF for PID were planned, using the proposed ePHENIX detector as an example.

By agreement with JLAB, they would perform initial studies of the MCP-PMT. Modifications to the LAPPD MCP-PMTs were not supported at the present time by the EIC R&D funding. However, our group is still interested in our proposal to develop UV improved MCP-PMTs, and will present updated plans for the FY2016 cycle.

What was achieved?

Two 1st prototype 24 gap mRPC's were developed by BNL, UIUC, and Howard to start getting our groups familiar with the detailed issues of the design and construction. The design and size of these 1st prototype mRPCs was influenced by the PHENIX TOF.W mRPC-based detector. It is composed of a stack of 20 thin glass layers for separating the gas gaps, 8 cathode layers for producing electric fields crossing glass and gas gaps, and 5 PCB layers for picking up induced signal from image charge. The thickness of the thin glass is 0.55 mm and they are separated by 0.2 mm diameter fishing line used as spacers to keep a uniform width of gas gap. A 1.1mm thick glass also used for insulating the cathode layer. This initial detector

has 4 copper readout strips. The cathode layer is made of carbon painting on the both top and bottom surface of PCB except for outer two PCBs which have cathode at inner side only. Figure 1, (a) top shows the picture of 1st prototype mRPC, (a) bottom shows layout of signal strips on the PCB (c) shows stack of glass, PCB, and cathode of 1st prototype mRPC.

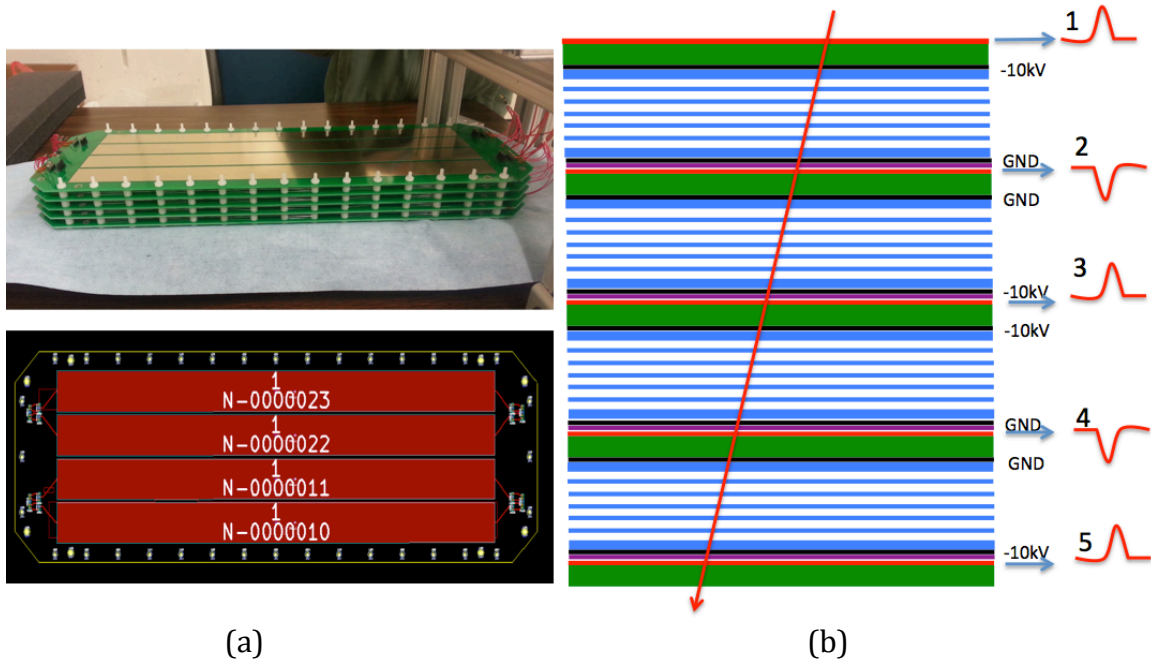


Figure 1 (a) Top shows the picture of 1st prototype mRPC, bottom picture shows the PCB design for signal strip. (b) shows cartoon of mRPC stack and the output signal polarities depending on the layers of PCB. The red color indicates signal strip, green color indicates PCB, black color indicates carbon cathode, and blue color indicates thick and thin glass layers. The red color arrow shows the direction of an incident cosmic muon or charged particle.

In figure 1(b), the output signals from the layers of signal strips have two polarities depending on the sign of applied high voltage to the cathode. For the readout, the signals are combined by polarity. For example, for the positive output signals, numbers 1, 3, 5 are combined. For the negative signals, numbers 2 and 4 should be combined. Differential preamplifiers are used for the signal amplification of both positive and negative signals. The DRS4-V4 evaluation board was used for digitizing the output pulse from the preamplifier with sampling rates of 5 GHz. The two prototype mRPCs were tested at FNAL Test Beam Facility (FTBF) during Feb 2014 for two weeks with hadron beams as part of the T1048 program. In figure 2, one can see the two prototype mRPCs, each of which were set inside the two gas cylinders, and placed downstream of the beam line in the FTBF beam test area.

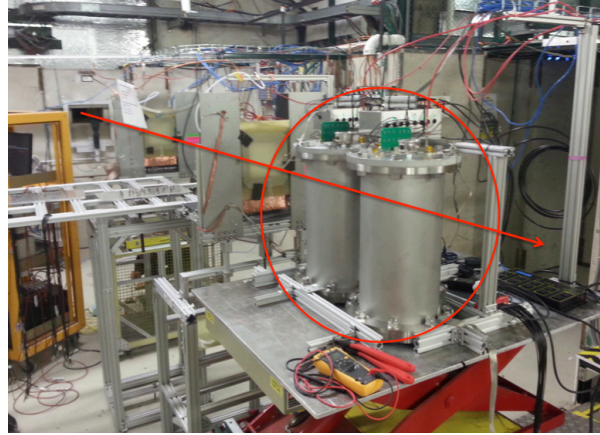


Figure 2 shows setup for the two prototype mRPCs at Beam Test Area in FNAL.

From this 1st prototype mRPC test, some possible improvements could be summarized below for the next prototype mRPC.

1. After assembling the prototype mRPC, we found that the surface of outer PCBs were bent when we tight all screws along the edge of PCBs. This caused the broken glasses inside.
→ Add a ridged material like honeycomb plane to outer PCBs to keeping a very flat surface.
2. Silver epoxy used for the connection between high voltage cable and the edge of cathode on the PCB added additional thickness compared to the near area so it broke insulating glass.
→ Modify PCB design not to use any conductive epoxy for the connection under the installation glass.
3. Combining the same signs of signals from different layer of PCBs was difficult.
→ Need to improve design of the readout side of PCB.
4. Reducing the thickness of the glass and width of gas gap could increase a detector efficiency and timing resolution.
→ Find alternative thin material for replacing glass. There is thinner glass but the price increase dramatically, so finding other low cost materials like Kapton, Mylar, and others would be useful study.
5. Need to protect the electric circuit of differential preamps from being burned out when it is connected to the mRPC.
→ Need to implement diode clamps to prevent reverse-bias damage?

2nd Prototype Design

Based on the experience gained from the 1st prototype mRPC, we worked on an improved design for a second prototype mRPC, most of which was done by the UIUC post-doc Ihnjea Choi. For the 2nd prototype mRPC, we followed the same configuration - same glass and same width of gas gaps, and only after this is fully successful we will build the next version of prototype using different materials to

reduce the thickness of the dielectric (currently glass) and reduce the width of the gas gaps. This 3rd design should be the one to show improved timing performance.

In figure 3 (a), the top picture shows the new PCB layout for the 2nd prototype mRPC. The outer dimension of PCB is 71mm x 196mm and the size is about half of the first prototype, which helps with turn-around in the construction. Each strip size is 10mm x 169mm and the corners of the strips are rounded. In figure 3(a) the bottom picture shows the side view layout of the 2nd prototype mRPC. The green color indicates the PCB, blue color indicates signal strips, black color indicates the HV electrode, and red color indicates the new HV pad that will help to make the connection between the HV input cable and the graphite electrode. The electrode will be coated on the top and bottom surface of the PCB by using a carbon spray. The copper strips are placed in the middle layer of PCB to keep the same distance to the two electrodes on the both side of PCB. Figure 3 (b) shows how to arrange the 5 PCBs to form the 4 stack configuration, and how to combine the positive and negative signals separately. The position of each signal outlet at the edge of PCB is slightly shifted from the center of signal strip. This is because when the 2nd and 4th PCBs are rotated by 180 degree relative to the 1st, 3rd, and 5th PCB then the positive and negative signals can be easily combined.

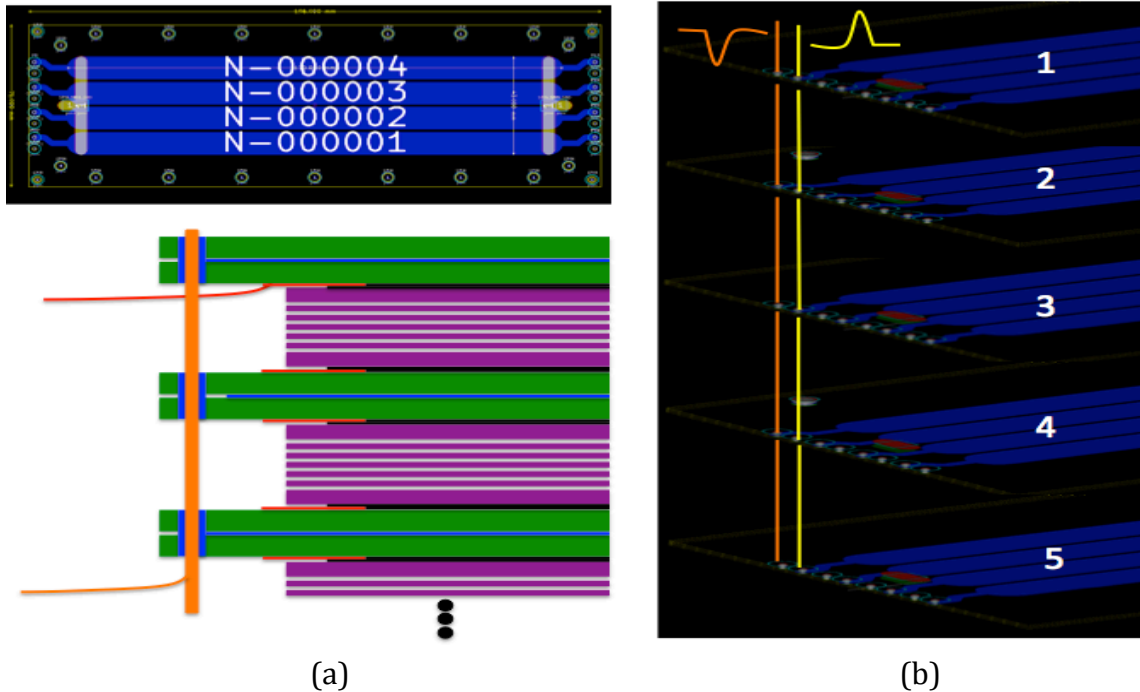


Figure 3 (a) Top, PCB design for 2nd prototype mRPC. Bottom, Side view
(b) shows how to combine signal separately from 5 layers of PCB.

The new PCB design for the 2nd prototype is now completed and 12 PCBs have been ordered for making two prototype mRPCs. All the remaining thin glasses used for the previous prototype mRPC were shipped from BNL to UIUC.

Cosmic Test Stand at UIUC

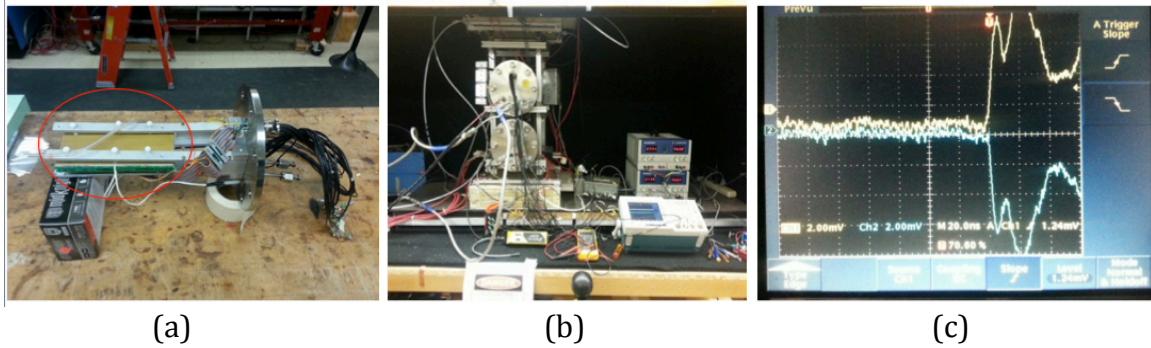


Figure 4. (a) A Tsinghua ToF mRPC mounted on the head of gas cylinder. (b) UIUC cosmic ray test system. The Tsinghua mRPC put into the top cylinder. (c) A pair of positive and negative signals from one of channel from the detector with -14kV HV and gas mixture of 95% Freon, 4.5% Iso, and 0.5% SF₆.

For the cosmic ray test of these new prototypes at UIUC, a Tsinghua built mRPC was mounted to UIUC cosmic ray test stand and it has been operated for checking all readout, gas, and trigger systems. Figure 4 (a) shows a picture of the mRPC, (b) picture of UIUC cosmic ray test stand, (c) Signal from a pair of positive and negative channels from the detector. The test stand is completed and ready for the 2nd prototype.

Simulations of the mRPC Detector

Initial simulations of the detailed physics processes have been started, and are publicly available (open source) at https://github.com/mickeychiu/mrpc_garfield. The software currently implements a single gas gap. The gas gap is segmented into 1000 tiny slices of gas. In each of these slices the simulation generates initial ionized electrons using HEED++, and then calculates the electron and ion density in each slice as a function of time. The totality of the slices constitutes the avalanche. The development of the avalanche with time is computed using GARFIELD and MAGBOLTZ to determine the Townsend coefficient α , the attachment coefficient η , and the drift velocity v , as well as the transverse and longitudinal diffusion coefficients. The simulation is approximately halfway done at the moment, with work remaining on calculating the induced charge on the pickup cathodes, combining many single gas gaps into a multi-gap detector, and implementing the space charge effects.

What was not achieved, why not, and what will be done to correct it?

For the 6 months covered during this period we feel that we have achieved our intended goals.

What is planned for the next funding cycle and beyond? How, if at all, is this planning different from the original plan?

The current status and future milestones for the 2nd and 3rd mRPC prototypes are listed here.

mRPC - Prototypes

Design of 2nd prototype mRPC : done

Cutting the glass : Jan. 2015

Carbon spray on the PCB : Jan. 2015

Assembly of 2nd prototype mRPC : Feb. 2015

Finding thinner glass and quote: present ~ June 2015

Finding other materials for replacing thin glass and quote: present ~ June 2015

Design for 3rd prototype mRPC : not fixed.. maybe early June. 2015

mRPC – readout

Differential preamplifiers: Jan 2015.

One DRS4-V5 evaluation: Jan 2015

Installing DAQ software and analysis software : Feb. 2015

mRPC – Gas

Freon-134a, Isobutane, SF6: ready

Gas mixing system: ready

mRPC – High Voltage

CAEN SY3527 and A1526N module, Voltage up to -15kV: ready

A positive high voltage, A1526P, needs repair: March 2015

mRPC – Cosmic Ray Test and Beam Test

Two gas volumes available for accommodating prototype mRPCs: ready

Small scintillation detectors for trigger: ready

Setup Si-Tracker: March 2015.

Beam Test: Oct. 2015.

The primary goal is a 3rd set of prototypes that will be ready for a beam test in October 2015 which should be the ones which test our ideas for improving the timing resolution for mRPC's. We also remain interested in LAPPD MCP-PMTs. We

have begun discussions with eRD11 to form a PID consortium, which will help in organizing the LAPPD MCP-PMT effort.